AN1702
Application note

ST485EB for e-meter applications

Introduction

This application note explains the procedure for designing the RS-485 communication lines in energy metering applications which helps e-meter engineers build their projects.

Energy meters are used to monitor personal usage of electricity. In the past only one kind of e-meter was used which was an electromechanical device and required human intervention for the periodic on site data collection. The new frontier in energy metering is a new generation of electronic e-meters providing new features such as network data collection, auto-diagnosis and time-scheduled accounting differentiation in order to define different energy costs on differently defined time segments.

These meters provide monitoring, analysis and data storage on energy usage.

The network connection between meters allows for centralized data collection with the significant advantage that manual meter reading is no longer necessary. Moreover, it makes locating meters easier, since external accessibility (in order to get a manual reading) is unnecessary.

The network architecture can be of different types: bus, daisy chain, tree structure and so on. One of the most efficient is bus architecture. Each meter is connected to the main bus through a stub, which is kept as short as possible. The communication should be bi-directional. Each meter, in fact, needs to send data, as well as receive data from the central control, such as permission to send tariff upgrades, diagnostic routines, setups, etc.

Modern communication technologies offer several choices of communication with meters. One of these methods is the use of a twisted pair cable, using RS-485 differential transmission. It offers a wide choice of transceivers available on the market, high data rates over long line lengths, high noise rejection, and good electrical robustness that makes it suitable in rugged environments.

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1 RS-485 interfaces

With RS-485 two kinds of communication lines can be built: half or full duplex. A full duplex line requires four wires, and each node can simultaneously send data on two wires, while receiving from the other pair of wires. A half duplex line uses only one pair of wires for both sending and receiving, and in this case only one node at any one time can send data on the line (see *Figure 1* and *Figure 2*). This means that two or more nodes, sending contemporaneously data to the bus, cause errors in data transmission. It is the application engineer's responsibility to choose the proper network management method in order to avoid this problem. This choice may be constrained by the need to use a pre-defined protocol on the network, or by the limitation of the calculated power of the network controller.

Figure 1. RS-485 half-duplex network

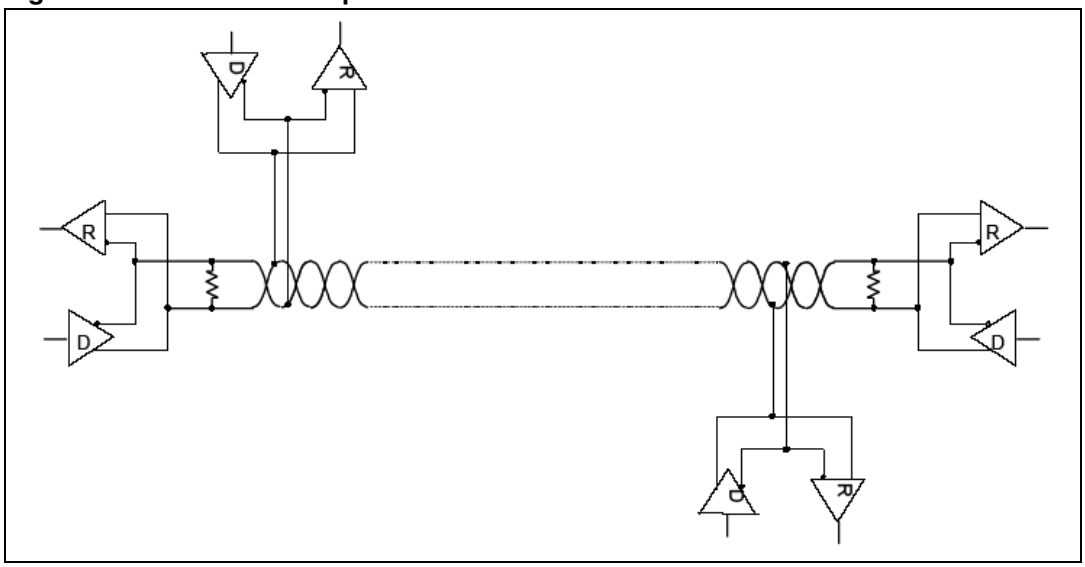
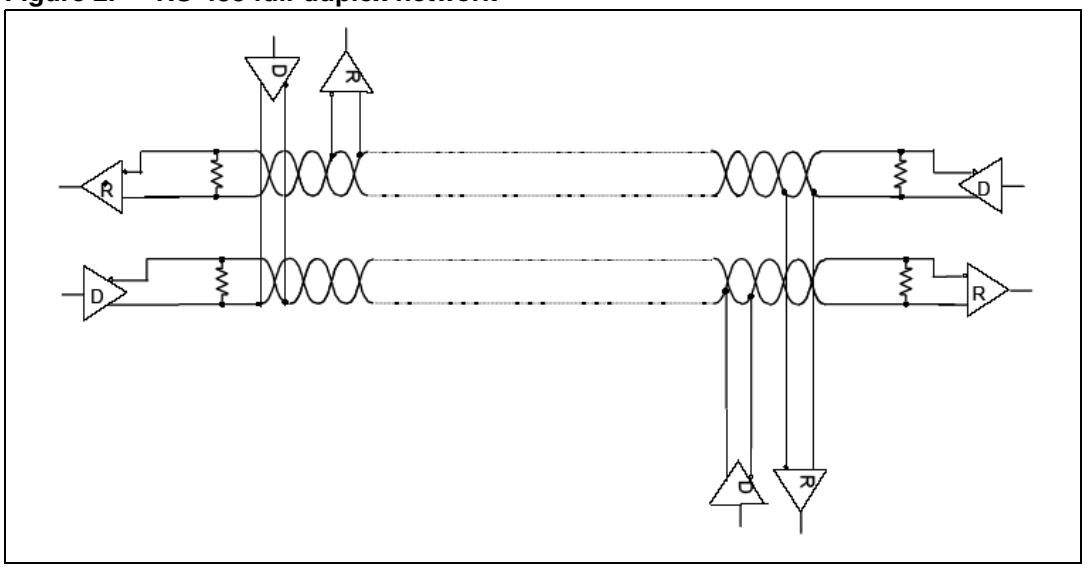


Figure 2. RS-485 full-duplex network



2 RS-485 advantages

Data transmission in e-meter applications occurs in noisy environments. Meters are connected to the ac voltage, often located near industrial machinery or home appliances and the transmission line is often very long (hundreds of meters) allowing atmospheric noise to degrade signal quality.

For these reasons, RS-485 signaling is particularly relevant. Its differential drivers and receivers, reject external noise (theoretically coupled equally into both lines) with high field strength.

Project equipment using RS-485 signaling requires the application of some rules. Differential lines must be kept close to each other, the use of a twisted pair cable is recommended and the board layout should be done with traces of equal length for the differential signals. Impedance matching also has to be considered in order to avoid signal reflections.

3 Signal levels

RS-485 drivers must produce a differential output voltage of at least 1.5 V into a 54 Ω load (usually the lines are terminated at both ends with a 120 Ω resistor; each driver seeing a 120/2=60 Ω load, 54 Ω being the worst case (10% tolerance). Receivers must detect a differential voltage as low as 200 mV. This is because if a degradation of the signal occurs across the line, the communication must not be affected. However, the driver differential output voltage depends on its output current capability. If many receivers are connected to the line, the driven load seen by the driver increases, as receivers are added to the bus, requiring more current. The RS-485 standard defines a unit load (UL), which is about a 12 kΩ resistance over the bus voltage range interval (-7 to +12 V). RS-485 drivers must generate the required output minimum voltage (1.5 V) with at least 32 unit loads on a terminated bus with a 120 Ω resistor on each end of the line.

The ST485EB is a half-duplex RS-485 transceiver with a low unit load. A network provided with these 1/8 UL transceivers allows interconnection of 256 nodes, driven by means of a standard compliant driver, without overloading it.

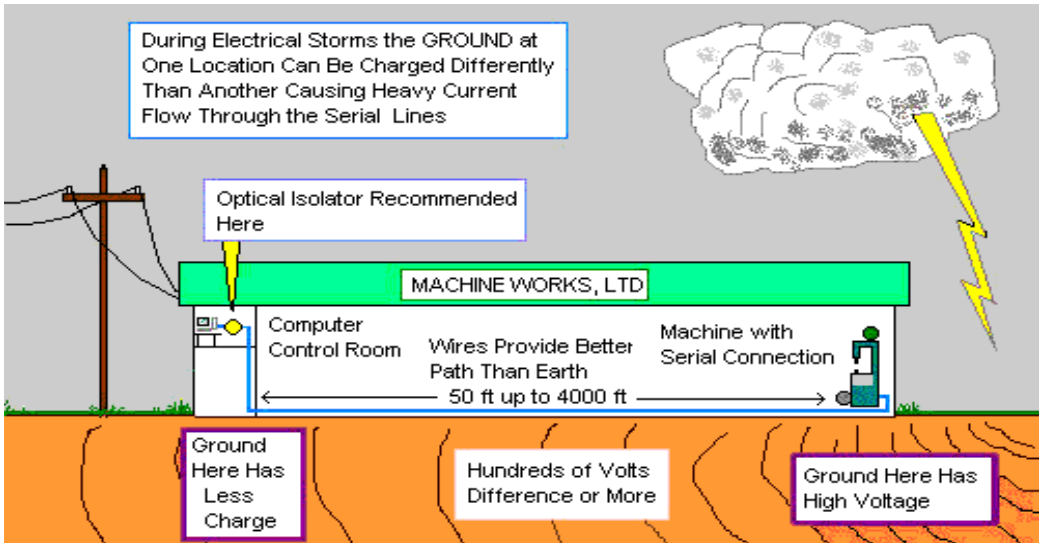
4 Bus lengths

The signal quality is evidently affected when the length of the bus increases. The most significant factor is the attenuation of the high frequency components of the signal. This produces slackening of the rising and falling edge of the signal as well as jitter and inter-symbol interference. All these factors must be taken into account when considering the cable length and signaling rate. Most e-meter applications require signaling rates below 250 kbit/s. With these rates, the signal degradation is less evident for cable lengths up to 1 km. The ST485EB is suitable for these signaling rates. Its driver outputs have a slew rate limitation, which reduces EMI and signal reflections on the line, allowing very low signal degradation over long distances.

5 Network isolation

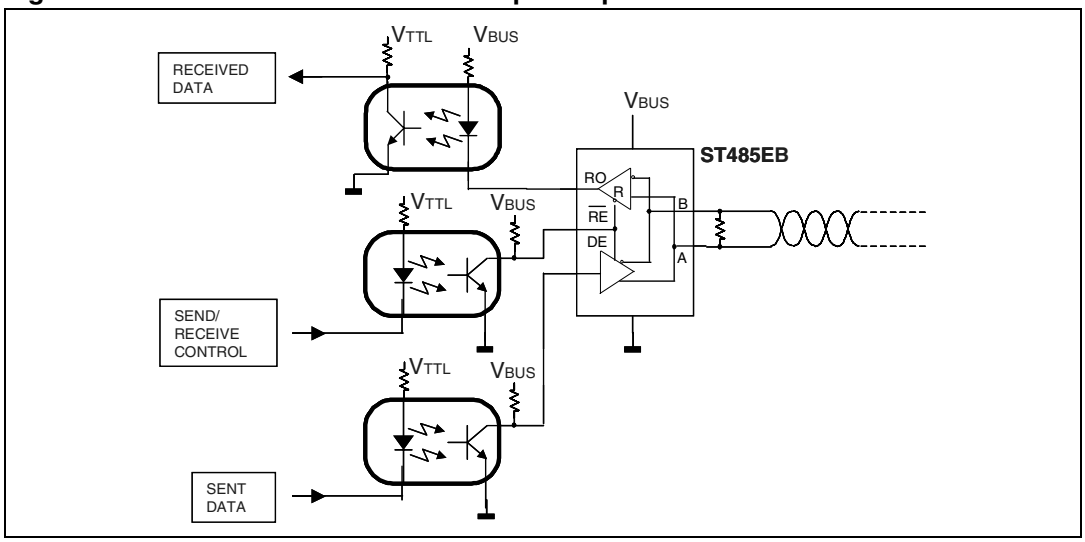
Due to the long distance covered by the network, many factors such as ground loops, external noise, spikes, electrical storms, or common-mode voltages exceeding the maximum voltage range (-7 V to+12 V), can bother or, in some cases, damage the equipment connected to the TTL side of each transceiver (see *Figure 3*).

Figure 3. Dangerous ground shifts in a common situation


During Electrical Storms the GROUND at One Location Can Be Charged Differently Than Another Causing Heavy Current Flow Through the Serial Lines
Optical Isolator Recommended Here
MACHINE WORKS, LTD
Computer Control Room
Wires Provide Better Path Than Earth
Machine with Serial Connection
50 ft up to 4000 ft
Ground Here Has Less Charge
Hundreds of Volts Difference or More
Ground Here Has High Voltage

In order to avoid this, it is advisable to electrically isolate the equipment from the bus. In *Figure 4* an example is shown of isolated transceivers, requiring the use of optocouplers at any single-ended (T_{TL} input/output) terminal. Note that two isolated power supplies are used: one for the transceivers and the related sides of the optocouplers connected to them (V_{BUS}), the other one for the equipment and the other sides of the optocouplers (V_{TTL}). These two supplies should be isolated from each other, and derived from different power generators or transformer windings.

Figure 4. RS-485 terminal node with optocouplers



The choice of proper optocouplers should be based on rise and fall times, which are related to the signaling rate. The RS-485 requirements for the signal quality are that the rise (or fall) time should not exceed 30% of the bit time (reciprocal of the signaling rate). For a signaling rate of 250 kbit/s, the maximum rise or fall time of the optocouplers is:

Equation 1

$$0.3 \cdot (\text{bit time}) = 0.3\left(\frac{1}{250\ \text{kbps}}\right) = 1.2\ \text{msec}$$

Therefore, an optocoupler with rise/fall times faster than 1.2 msec is required. The biasing resistors should be selected taking into account the current characteristics of the optocouplers, and the threshold voltages of the transceiver input pins, in order to ensure a reliable driving of the transceiver.

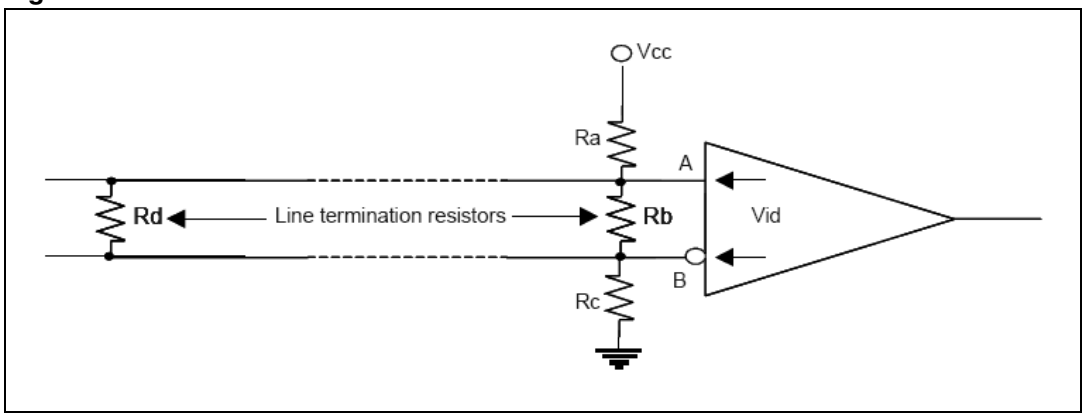
6 Fail-safe biasing

In an RS-485 network, a driver is always active on the line. Therefore, each receiver has differential input voltages, which exceed the 200 mV minimum threshold voltage, ensuring a known logic state at its output. When a receiver is disconnected from the bus (receiver inputs floating), its output assumes an undetermined logic state. The ST485EB has an internal fail-safe feature, which avoids this problem. A weak internal biasing ensures a receiver differential voltage higher than 200 mV, and therefore a valid logic state at its output under floating inputs conditions.

A different situation occurs when there are no active drivers on the network (idle-bus). In this case, the receivers are connected to the bus and to the termination resistors. The termination resistors decrease the differential voltage near 0 V, and the internal fail-safe is not able to ensure a proper voltage level.

Some transmission protocol (for example the UART protocol) requires a high logic state of the bus when in idle state. In order to solve this problem, two biasing resistors should be applied to the two line wires, giving a proper biasing of the line (see also the application note "fail-safe biasing for ST485"). In a terminated bus with a 120 Ω termination resistor at each end, the equivalent resistance is 60 Ω (120 Ω/120 Ω). In order to produce a differential voltage at its leads higher than 200 mV, a current of 4 mA should flow into it. In order to guarantee this current without unmatching the characteristic impedance of the line, 500/600 Ω resistors should be used (see *Figure 5*).

Figure 5. External fail-safe and line DC termination



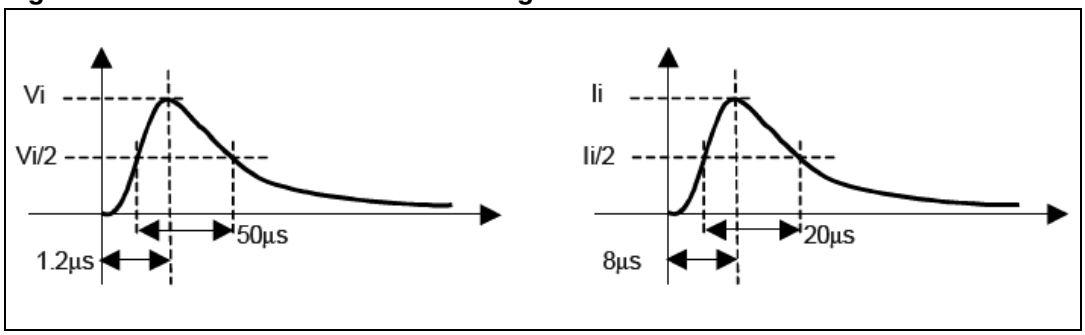
The external fail-safe circuitry should be placed at one end of the bus or at each end of it, using, in this case, twice the value calculated for one biasing circuit (1 K/1.2 KΩ) and, of course, it should not be disconnected for any reason.

The external fail-safe circuitry draws current; therefore it loads the driver outputs. This extra load should be taken in account defining the maximum number of transceivers allowed on the bus. The equivalent load of the fail-safe circuitry, seen by the active driver is, for Ra = Rc = 500 Ω, 24UL. Since the maximum allowed on the bus is 32UL, the available unit loads should be 32UL - 24UL = 8UL. Using the ST485EB (1/8UL per transceiver) the maximum number of transceivers should be: 8UL / (1/8UL per transceiver) = 64 transceivers.

7 Transient voltage suppression

Transient voltage surges are generated generally by inductive load switching, for example, the equipment starts and stops, lightning strikes, etc. The standard IEC 61000-4-5 Immunity Test describes a method to test circuits with a waveform simulating these conditions (see *Figure 6*).

Figure 6. IEC 61000-4-5 transient voltage test V and I waveforms

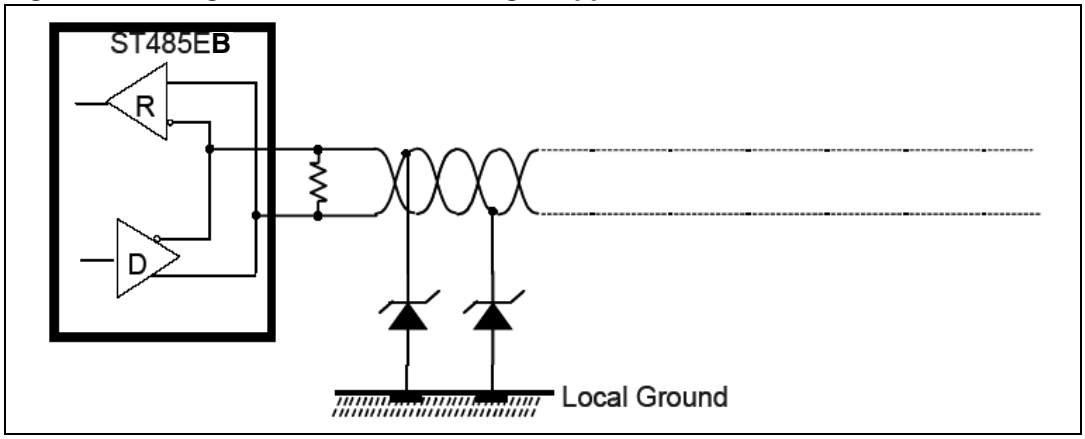


Surge voltages inducted on both differential lines do not affect the entire system operation, if the bus is isolated, and the ground voltage shift generated does not exceed the maximum ratings. However, the use of additional transient voltage suppressors (TVS) is advisable, in order to protect against surges in case of miswiring, incorrect grounding and other fault conditions. ST offers a wide range of TVS. Visit the site: http://eu.st.com/stonline/discretes/index.shtml. The selection criteria are the stand-off voltage (VRM), the clamping voltage (VCL) and the peak power dissipation (PD). The stand-off voltage must not exceed the operating common mode voltage range (-7 to +12 V), in order to avoid clamping during the normal operation, while the clamping voltage must be low enough to hold the line voltage with no damage to the protected circuits. The peak power dissipation is the product of the clamping voltage and the peak current that can be managed by the TVS without being harmed. One TVS suitable for a RS-485 network is the ST's SMA12CA. It has:

Equation 2

$$V_{RM} = +/- 12\ V; V_{CL} = 19.9\ V\ @\ I_{PEAK} = 20A; P_D = 400\ W$$

Figure 7. Usage of the transient voltage suppressors in the RS-485 network



8 ESD protection

Common situations such as handling, connection and maintenance can create electro-static discharges (ESD), which can damage related devices. The use of transceivers with high ESD immunity in e-meter applications is recommended. In order to evaluate ESD immunity, two standards are largely used at this time: the JEDEC standard (Human Body Model), which simulates the ESD of a human body contacting the device, and the ISO standard (IEC 61000-4-2), which simulates the ESD of a human body handling a tool (screwdriver, or a metallic connector, etc.), approaching (Air Discharge) or contacting (Contact Discharge) the device. The IEC 61036 standard requires that the device be immune to contact discharges (ISO IEC 61000-4-2) of 8 kV, while the DL/T 645 standard requires meter equipments to tolerate 15 kV (HBM) discharges. The ST485EB is compliant to both these specifications.

9 Revision history

Table 1. Revision history

Date	Revision	Changes
11-Sep-2006	1	First release
28-Sep-2007	2	– No content changes, document reformatted. – ST485ER replaced by ST485EB

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